Effectiveness of Constraint-induced Movement Therapy in Chronic Stroke Patients

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Objective : *The purpose of this study was to evaluate the effectiveness of constraint-induced movement therapy (CIMT) in dexterity with Action Research Arm Test (ARA test), hand grip strength, pinch strength of affected upper extremity in chronic stroke patients.*
Material and Method : *An observer-blinded randomized control trial, 69 chronic stroke patients were allocated either to constraint-induced movement technique (n = 33) or conservative treatment (n = 36). The CIMT group received 6 hours of daily affected-upper-extremity training and restrained unaffected upper extremities for 5 days per week, totally 2 weeks. The control group received bimanual-upper-extremity training by conservative neurodevelopmental technique without restrained unaffected upper extremities for 2 weeks.*
Results : *The CIMT group had ARA scores, pinch strength of affected upper extremities statistically significant higher than the control group at $p < 0.05$, but the hand grip strength had no statistically significant difference, $p > 0.05$.*
Conclusions : *CIMT of unaffected upper extremities has an advantage for chronic stroke patients which may be an efficacious technique of improving motor activity and exhibiting learned nonuse.*

Keywords : *Constraint-induced movement therapy, Chronic stroke, ARA scores, Hand grip and pinch strength*

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Stroke is the third leading cause of death in the United States[1]. In Thailand, Public Health Statistics show that stroke has been on the increase[2]. A great majority of stroke patients in rehabilitation improve in function[1], but the improvement is quite variable from one patient to the other[3]. Approximately, 80% of stroke patients survive the acute phase. Although most patients regain their walking ability, 30% to 66% of the survivors are no longer able to use the affected arm[4]. The recovery process of the function of the upper extremity is often slower than that of the lower extremity[5,6]. According to the theory of "learned nonuse", repeated disappointment in attempts to use the affected arm in the acute and subacute phases can lead to negative reinforcement of the use of the affected arm[7]. Although motor function may gradually return as the combined result of spontaneous recovery and rehabilitation, actual use often seems much less than potential use[8].

Few, if any, rehabilitation methods are proven to restore function or overcome learned nonuse in the affected upper extremity following a stroke. The demanding society of today and health care environment often necessitate the attainment of the highest functional level possible in the shortest time. For this reason, the therapeutic focus a patient's choice is often on compensating for lost movement by replying primarily on the side not affected by the stroke for activities of daily living (ADL)[9-12]. Performing ADL tasks with one arm may still leave the individual with limited abilities[13,14]. Persistent reliance on one side of the body may also result in certain consequences, such as overuse syndromes, pain, frustration, and embarrassment[13,15,16].

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Constraint-induced movement therapy (CIMT) of the upper extremity affected by hemiparesis has been credited with hastening the cortical map reorganization process in nonhuman primates[17] and in humans[18]. In other methods of stroke treatment, patients learned to use the unaffected extremity for ADL. Such approaches of treatment may faster learned nonuse of the affected extremity. Learned nonuse is proposed to be a phenomenon in which an individual effectively forgets to use the affected extremity because of the extreme difficulty of movement experienced immediately after the onset of stroke[9,18-20]. CIMT is thought to offset learned nonuse, as it was developed to improve purposeful movement of the affected extremity by restricting the use of the unaffected upper extremity after stroke[19,20]. In fact, the main therapeutic factor in CMIT is the intensive use of the paretic limb[17]. A study has shown significant results in favor of the effectiveness of CIMT compared with equally intensive bimanual training based on Neuro-Developmental Treatment (NDT)[20]. Patients have shown significant increases in the daily use of their impaired limbs and an increase in the speed at which they carried out activities after parcipitating in CIMT. Patients have reported increased satisfaction level secondary to increased ability to use their affected extremity[9,19]. Furthermore, they have a greater rate of retaining recovered function, with evidence of sustained improvement as long as 2 years poststroke[17].

In Thailand, NDT is widely applied in stroke rehabilitation. Although the NDT method has never been proved more effective than other treatment modalities in stroke patients[21,22]. The authors never used or studied CIMT before. The main research question addressed in the present study is whether constraint-induced movement therapy for 2 consecutive weeks is more effective than bimanual training based on NDT in restoring dexterity and improving hand grip and pinch strength in chronic stroke patients.

Objectives

To find the effectiveness of constraint-induced movement therapy (CIMT) in dexterity with Action Research Arm Test (ARA test), hand grip strength, pinch strength of affected upper extremity in chronic stroke patients.

Study design

This was a prospective, randomized, observer-blinded clinical trial to define the effectiveness of constraint-induced movement therapy (CIMT).

Ethics

The study was approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand.

Material and Method

Study samples

Patients were recruited from the Department of Rehabilitation Medicine of King Chulalongkorn Memorial Hospital. Chronic stroke patients who met the following criteria were included: (1) age 18 to 80 years; (2) having a history of a single stroke; (3) the duration of stroke before the start of the study was between 1 to 10 years; (4) having a minimum of 20 degrees of active wrist extension and 10 degrees of finger extension; (5) Action Research Arm (ARA) test score < 51 (maximum score, 57)[23]; (6) being able to walk indoors without a stick, indicating no major balance problems; (7) no severe aphasia; (8) no sensory disorder; and (9) no severe cognitive impairments.

In an observer-blinded randomized clinical trial, patients were randomized individually into 2 groups by using the table of randomization. One group of patients received forced use treatment for 2 weeks; the other group received equally intensive bimanual training based on NDT for 2 weeks. All patients were treated in groups of 3-4.

Treatment

Patients were treated in groups of 3-4 in the outpatient clinic of the Department of Rehabilitation, Medicine of King Chulalongkorn Memorial Hospital. Every patient in each group received the same treatment for 2 consecutive weeks, 5 days a week, and 6 hours a day. All patients in the experimental groups had their healthy hands covered by glove for avoidance of using them. Patients were encouraged to use the affected arm at home during the 12 days of treatment, too. In the control group, patients were treated according to the NDT method.[24] All activities were performed bimanually and, if necessary, the affected arm was supported with the unaffected hand. Symmetry of posture and inhibition of inappropriate "synergistic" movements were emphasized.

Measurements

Because the experimental and reference treatments could not be applied simultaneously, the time intervals between treatment allocation and the start of the intervention varied. Baseline measurements were performed 3 to 5 days before the start of the treatment.

The second assessments took place 3 to 5 days after the end of the two-week treatment period.

a. Primary Outcome Measures

Dexterity was assessed by means of ARA test[23,26], which is an observational test consisting of 19 items focusing on grasping objects of different shapes and sizes, and gross movements in the vertical and horizontal planes. The performance of each motor task was rated on a 4-point scale, ranging from 0 (no movement possible) to 3 (movement performed normally)[26]. The scores on the individual items were added, yielding an overall sum score; the maximum obtainable sum score was 57 points. The validity and reliability of the ARA test have been found to be high in several studies[23,26].

b. Secondary Outcome Measures

Hand grip and pinch strength were measured by dynamometer three times and the mean of each value was scaled in kilogram.

In the literature, no estimates were found on minimal clinically important difference (MCID) for any outcome measures used in the present study. On the basis of clinical experience and reported estimates for similar outcome measures in different domains, the MCID was set at 10% of the total range of the scale[27]. Van der Lee et al[20] stated that the MCID for ARA test was 5.7 points, which reflects the difference between, for instance, not being able to grasp and lift 3 objects, and the ability to move 3 objects to a standardized (higher) level.

Statistical analysis

The General Linear Models for Repeated Measures option in SPSS 11.0 for Windows 2000 was used to analyze each outcome measure. General characteristic data was analyzed by using frequency distribution, percentage and test for the difference at 5% significant level by Chi-square test. ARA score, hand grip and pinch strength were analyzed by using median, range and percentage of change. The difference of ARA score, hand grip and pinch strength before and 2 weeks after CIM within each group were analyzed by Wilcoxon signed rank test. The difference of ARA score, hand grip and pinch strength before and 2 weeks after CIM between control and experiment group were analyzed by Mann-Whitney U-test. The level of statistical significance was set at $p < 0.05$.

Results

Demographic data

Sixty-nine chronic stroke patients were allocated either to constraint-induced movement therapy (n = 33) or to only conservative treatment (n = 36). There were 25 males (69.4%) and 11 females (30.6%) in the control group, 22 males (66.7%) and 11 females (33.3%) in the experimental group. The mean age in the control and the experimental group were 58.7 $\pm$ 4.2 and 60.1 $\pm$ 4.8 years old, respectively. Most of them were educated below high school level: 47.2% and 36.4% in the control and experimental group, respectively. Most cases were infarction: 75% and 57.6% in control and experimental group, respectively. Regarding the side of weakness, they were nearly equal in the control group; and mostly on the right side in the experimental group. The duration since onset of stroke was mostly during 1-3 years in both groups. All demographic data in both groups were not statistically significantly different by Chi-square at $P < 0.05$ as shown in Table 1.

Action Research Arm Test (ARA)

During the intervention period, a significant main effect of treatment was found in both groups. The percentage of change in total ARA test in the control group was less than 10%, i.e. 8.4%; and in the

Table 1. Demographic data of the study population

Characteristics	Control (N = 36)		Experiment (N = 33)		p-value[1]
	N	%	N	%	
Age (yr)					0.461
40-50	5	13.8	7	21.2	
51-60	9	25.0	12	36.4	
61-70	11	30.6	8	24.2	
71-80	11	30.6	6	18.2	
Gender					0.805
Male	25	69.4	22	66.7	
Female	11	30.6	11	33.3	
Education					0.691
Below high school	17	47.2	12	36.4	
High school	10	28.9	11	33.3	
College or more	9	25.0	10	30.3	
Etiology of stroke					0.125
Hemorrhage	9	25.0	14	42.4	
Infarction	27	75.0	19	57.6	
Side of weakness					0.572
Right	34	94.4	30	90.9	
Left	2	5.6	3	9.18	
Duration since onset of stroke(yr)					0.154
1 yr-3 yr	29	80.6	27	1.8	
3 yr-5 yr	6	16.6	2	6.1	
5 yr-7 yr	1	2.8	1	3.0	
7 yr-10 yr	-	-	3	9.1	

[1]P-value by Chi-square test, significant at $p < 0.05$

Table 2. Action Research Arm Test (ARA) before CIM, 2 weeks after CIM and percent change

Items of Action Research Arm Test	Control (N = 36) Median (Range)			Experiment (N = 33) Median (Range)		
	Before	2 wks after CIM	% change	Before	2 wks after CIM	% change
Grasp	14.0 (5-18)	15.5 (6-18)	9.7	12.0 (7-18)	18.0 (9-18)	33.3
Grip	8.0 (2-11)	9.0 (4-11)	11.1	8.0 (6-12)	12.0 (8-12)	33.3
Pinch	12.0 (0-16)	13.0 (0-17)	7.7	12.0 (4-18)	17.0 (7-18)	29.4
Gross movement	7.5 (1-9)	8.0 (1-9)	6.3	6.0 (4-9)	9.0 (6-9)	33.3
Total ARA	43.5 (10-51)	47.5 (15-54)	8.4	41.0 (26-51)	55.0 (30-57)	25.5

experimental group it was more than 10%, i.e. 25.5% as shown in Table 2.

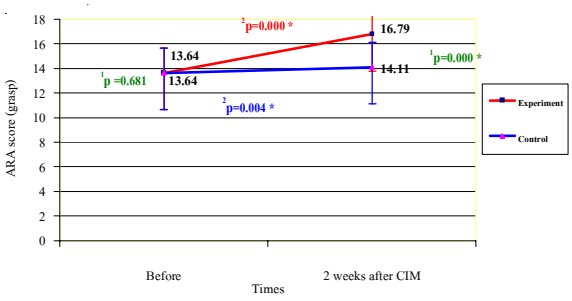
The mean ARA score of all items (grasp, grip, pinch, gross movement) and mean total ARA score at 2 weeks after treatment showed statistically significant improvement compared to those before treatment in both the control and experimental groups by Wilcoxon-signed rank test at $p < 0.05$, except the gross movement item in the control group as shown in Fig. 1-5.

The mean ARA score of all items (grasp, grip, pinch, gross movement) and mean total ARA before treatment showed no statistically significant difference between the control and the experimental groups by Mann-Whitney U test at $p < 0.05$ as shown in Fig. 1-5.

The mean ARA score of all items (grasp, grip, pinch, gross movement) and mean total ARA at 2 weeks after treatment in the experimental group was statistically significantly higher than the control group by Mann-Whitney U test at $p < 0.05$ as shown in Fig. 1-5.

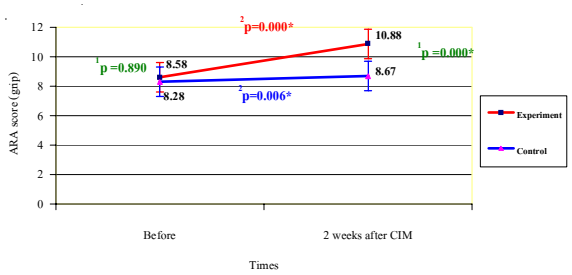
Hand grip and pinch strength

During the intervention period, a significant hand grip and pinch strength effects of treatment were found only in the experimental group. The median and



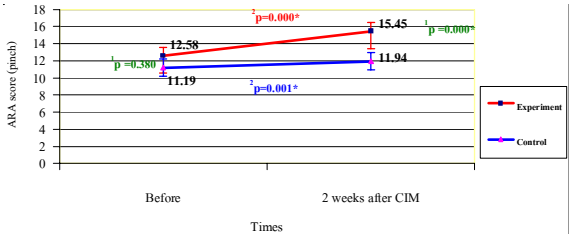
[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 1 Comparison of mean ARA score item grasp in each group and between group



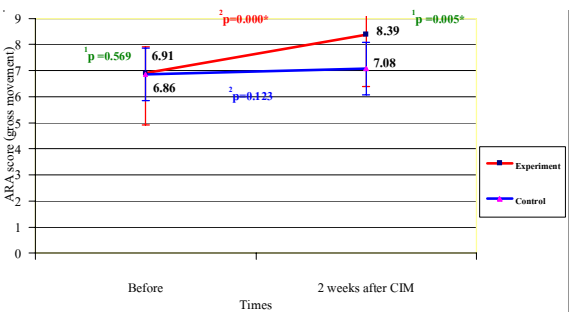
[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 2 Comparison of mean ARA score item grip in each group and between group



[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 3 Comparison of mean ARA score item pinch in each group and between group



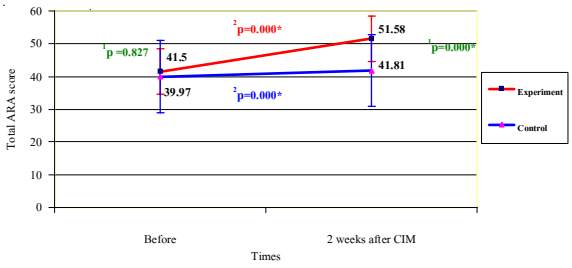
[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 4 Comparison of mean ARA score item gross movement in each group and between group

Table 3. Comparison of hand grip strength and pinch strength between before CIM and 2 weeks after CIM in each group

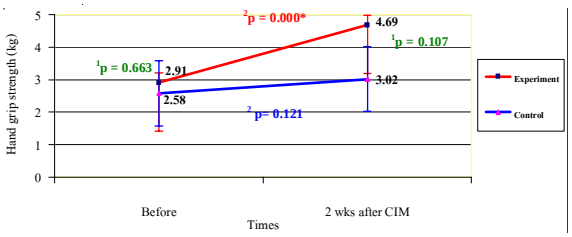
Dynamometer Test (Kg)	Control (N = 36) Median (Range)			Experiment (N = 33) Median (Range)		
	Before	2 wks after CIM	p-value[1]	Before	2 wks after CIM	p-value[1]
Hand grip	0.0 (0-15.0)	1.0 (0-18.5)	0.121	0.0 (0-15.0)	2.0 (0-17.0)	0.000*
Pinch	0.2 (0.0-0.9)	0.3 (0.0-1.8)	0.062	0.4 (0.0-0.4)	0.5 (0.0-1.5)	0.000*

[1]P-value by Wilcoxon signed rank test, significant at $p < 0.05$



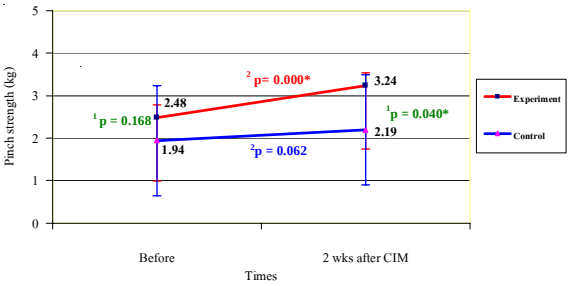
[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 5 Comparison of mean total ARA score in each group and between group



[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 6 Comparison of mean hand grip strength in each group and between group



[1] P-value by Mann-Whitney U test, significant at $p < 0.05$
[2] P-value by Wilcoxon signed rank test, significant at $p < 0.05$

Fig. 7 Comparison of mean pinch strength in each group and between group

Table 4. Comparison of hand grip strength and pinch strength after 2 weeks CIM in between group

Dynamometer test	Control (N = 36) Median (Range)	Experiment (N = 33) Median (Range)	p-value
Hand grip strength (kg)	1.0 (0-18.5)	2.0 (0-17.0)	0.107
Pinch strength (kg)	0.3 (0.0-1.8)	0.5 (0.0-1.5)	0.040*

[1] P-value by Mann-Whitney U test, significant at $p < 0.05$

mean hand grip and pinch strength at 2 weeks after treatment were statistically significantly higher than before treatment only in the experimental group by Wilcoxon-signed rank test at $p < 0.05$ as in Table 3 and Fig. 6, 7.

The mean hand grip and pinch strength before treatment showed no statistically significant difference between the control and experimental groups by Mann-Whitney U test at $p < 0.05$ as shown in Fig. 6, 7.

Only the mean pinch strength at 2 weeks after treatment in the experimental group was statistically significantly higher than the control group by Mann-Whitney U test at $p < 0.05$ as shown in Fig. 7.

Discussion

Hemiparesis is the most common deficit after stroke, affecting more than 80% of subjects acutely and more than 40% chronically[28]. Rehabilitation techniques have been more successful in restoring function in the lower limbs than in the upper limbs. Unfortunately, the upper limb function is more important for independent living and self esteem[28]. The time course for the recovery of upper limbs has been placed at 11 weeks post stroke. If functional recovery has not occurred by the 11th week, Nakayama et al[10] reported that further recovery of the upper limb function should not be expected.

A challenge to the accepted dogma that little can be done to restore function in the paretic limb in the post acute or chronic state has been offered by Taub

et al[7], proponents of Constraint-induced movement therapy (CIMT) to treat upper limb hemiparesis after stroke. Several investigations in the past 2 decades have demonstrated the effectiveness of CIMT with individuals who have an upper motor neuron lesion [7,9,17,18,20,29-32]. The basic components of CIMT involve restraint of the unaffected arm for 90% of working hours for a 2-to-3-week period in conjunction with repetitive training of the more affected upper extremity [7,9,18,20,30-32,34]. The less affected upper extremity is restrained with a mitt, sling, or glove. Patients typically participate in 6 to 7 hours of therapy a day plus home activities to be performed at home while wearing the restraint. This component of the program is intended to promote patients' adherence. The patients also keep treatment diaries to track the use of the affected arms when they are away from the clinic.

Since 1999, the effects of CIMT have been investigated with the use of neuro-imaging techniques with people who had a stroke more than 6 months previously. These studies included imaging via electroencephalogram[35,36], functional MRI[37], and focal transcranial magnetic stimulation[31,32]. These imaging techniques provide evidence of neuroplasticity following CIMT. The cortical changes seen with neuro-imaging correspond to the functional and laboratory improvements demonstrated with motor assessments. The patients in these neuro-imaging studies had typical CIMT (restraint 90% of working hours, 6 hours of training for 10 out of 14 days, and a daily dairy), with the exception of 2 studies in which participants received treatment for 8 out of 12-program days[32,35].

Subject criteria for most published CIMT research primarily included the amount of movement a patient must be able to be performed with the more-affected upper extremity[7,9,17,18,20,29,31-33,37,38]. All movement criteria included the ability to start from a resting position of forearm pronation and wrist flexion and actively extend each metacarpophalangeal (MCP) and interphalangeal (IP) joint at least 10 degrees and extend the wrist at least 20 degrees[39]. Individuals participating in these studies demonstrated improvement in the amount of use and quality of movement in the more-affected upper extremity as well as a carryover of skills from the clinic to the real world[7,9,17,18,20,29,30-33,37,38].

The results of the present study indicate that CIMT improved quality of movement in the more-affected upper limb as in previous studies[7,9,17,18,20,30-33,37-39]. The percentage of change in total ARA test in the CIMT group was more than MCID (i.e. 25.5%) as in another large randomized controlled trial[20]. Hand grip strength had no significant improvement as in other studies[28], while pinch strength showed significant improvement. The possible explanation were: (1) the repetitive tasks of CIMT training were focused on fine movement; (2) the only short duration of training (i.e.10 days) cannot improve strength of large muscles as function for grip strength, while it can improve strength of small muscles as function for pinch strength.

These results have been confirmed in another placebo-controlled experiment[40,41]. and further work has indicated that there is a family of technique that can be used to overcome learned nonuse[30,40-42]. Although most of the techniques involve constraining movement of the less-affected arm, two of them do not. The common factor seems to be repeatedly training the paretic arm. Any technique that induces a patient to use an affected extremity for many hours a day for a period of consecutive weeks should be therapeutic efficacious. This factor is likely to produce the use-dependent cortical reorganization found to result from CIMT therapy[28,31,3236] and is presumed to be the basis of the long-term increase in the amount of use of the more-affected extremity.

In the control group with NDT training, subjects also had statistical increment of all items of ARA and total ARA at 2 weeks after training compared to the baseline. These results have been confirmed by other works that repetitive practice is an important factor in stroke rehabilitation[43-47]. Wolf et al[9,38] carried out an experiment involving only constraint of the less-affected arm without massed training, which is half of the published CIMT therapy protocol (a procedure now termed "the force use paradigm"). The treatment effect was significant but rather small (effect size = 0.2). Taub and et al[7] applied both parts of the CIMT therapy protocol to the rehabilitation of patients with chronic upper limb hamiparesis. The treated group showed a significant increase in the skill or quality of movement, and a much larger increase in real-world use over the 2-week period. Moreover, they showed no decrease in real-world arm use when tested 2 years after the treatment. Control participants who also had mass training without restraint the less-affected arm also had much greater movement of their more-affected arm and showed no change or a decline in real-life arm use over the same period.

The result of the present study revealed that both mass training of NDT and CIMT can improve dexterity of the affected arm using ARA. While the hand grip and pinch strength improve only in the CIMT group. Therefore, CIMT can be another alternative

rehabilitation training technique that had statistically significant improvement than NDT technique. However, the authors suggest further study of real-world arm use for long-term period.

Conclusion

CIMT of unaffected upper extremities has an advantage for chronic stroke patients which may be an efficacious technique for improving motor activity and exhibiting learned nonuse.

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ประสิทธิผลของเทคนิคจำกัดการเคลื่อนไหวของแขนข้างที่ดีในผู้ป่วยโรคหลอดเลือดสมองเรื้อรัง

อารีรัตน์ สุพุทธิธาดา, นิจศรี ชาญณรงค์ สุวรรณเวลา, สวิตา ธรรมวิถี

จุดประสงค์ *: เพื่อศึกษาประสิทธิผลของเทคนิคจำกัดการเคลื่อนไหวของแขนข้างที่ดีเป็นเวลา 2 สัปดาห์ ในแง่ความคล่องแคล่วในการใช้แขนข้างที่อ่อนแรง ซึ่งวัดโดย Action Research Arm test (ARA test) ความแข็งแรงของมือและนิ้วมือซึ่งวัดโดย hand grip and pinch strength dynamometer ในผู้ป่วยโรคหลอดเลือดสมอง*

วิธีการศึกษาวิจัย *: การศึกษาครั้งนี้เป็น observer-blinded randomized control trial ในผู้ป่วยโรคหลอดเลือดสมองเรื้อรัง 69 คน แบ่งเป็นกลุ่มทดลอง 33 คนและกลุ่มควบคุม 36 คน กลุ่มทดลองได้รับเทคนิคจำกัดการเคลื่อนไหวของแขนข้างที่ดีนาน 2 สัปดาห์ ๆ ละ 5 วัน ๆ ละ 6 ชั่วโมง ส่วนกลุ่มควบคุมได้รับการฝึกแขนและมือทั้งสองข้างด้วยวิธีดั้งเดิมโดยไม่ได้จำกัดการเคลื่อนไหวของแขนข้างที่ดี นาน 2 สัปดาห์*

ผลการศึกษา *: ค่าเฉลี่ยของคะแนนความคล่องแคล่ว (ARA test) ความแข็งแรงของนิ้วมือ (pinch strength) ระหว่างกลุ่มที่ฝึกเทคนิคจำกัดการเคลื่อนไหวของแขนข้างที่ดี กับ กลุ่มที่ฝึกวิธีดั้งเดิม ภายหลังการฝึกที่ 2 สัปดาห์ แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) แต่ความแข็งแรงของมือ (hand grip strength) ระหว่างกลุ่มที่ฝึกเทคนิคจำกัดการเคลื่อนไหวของแขนข้างที่ดีกับกลุ่มที่ฝึกวิธีดั้งเดิม ภายหลังการฝึกที่ 2 สัปดาห์ ไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($P > 0.05$)*

สรุป *: เทคนิคการจำกัดการเคลื่อนไหวของแขนข้างที่ดีร่วมกับการฝึกแขนข้างที่อ่อนแรงมีประสิทธิภาพในการเพิ่มความสามารถในการใช้งานและการทำกิจกรรมต่าง ๆ ในผู้ป่วยโรคหลอดเลือดสมองเรื้อรัง โดยการยับยั้งการเรียนรู้ไม่ใช้แขนข้างอ่อนแรง*